IV

AËROLOGY.

By WILLIAM R. BLAIR.

The treatment of this subject in one paper must necessarily be general. An attempt will therefore be made to cover the ground and indicate points of contact between aërological observation and aëronautics, leaving argument and details of methods to a fuller treatment of the subject which, it is hoped, may appear in the near future.

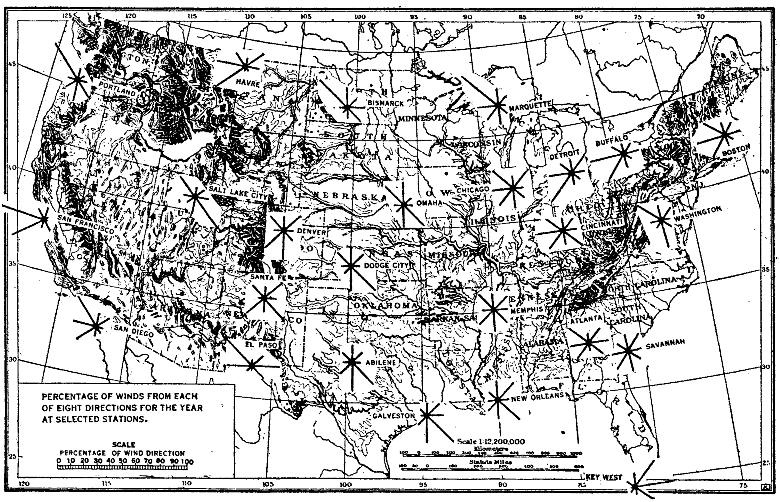

FIG. 1. Percentage of winds from each of eight directions for the year at selected stations.

Means of observations already reduced and compiled will be used in the discussion, not with the idea that these means will fully serve the aëronauts' purpose, but that they indicate standard conditions which to some extent show what may be expected at any time and place and should be in mind for comparison with the individual

observations in the region navigated. These observations on the spot are of fundamental importance and in practice cannot be safely set aside for forecasts or the indications of means as to the upper air conditions.

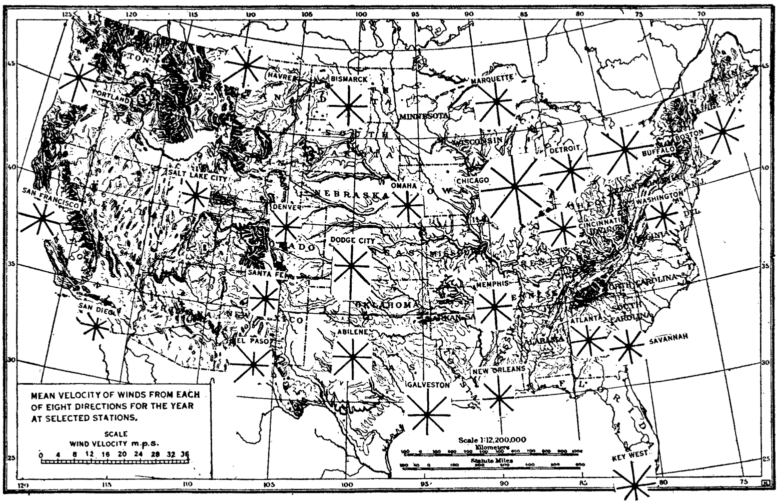

FIG. 2. Mean velocity of winds from each of eight directions for the year at selected stations.

Charts of means are in a sense the aëronauts' charts of the medium he navigates, but it must be kept in mind that these charts, in which results of observations are usually shown with reference to surface pressure distribution, are to be used with the current weather map.

Observations are made by means of kites, captive balloons and free balloons. Kites and captive balloons carry automatically recording instruments which record continuously temperature, pressure, humidity and speed of movement of the air. The free balloons used are of two sorts, sounding balloons and pilot balloons. The former carry an instrument which automatically records temperature, pressure and humidity of the air. Observations of air movement are obtained by means of continuous theodolite observations upon the balloons. In the case of sounding balloons, heights may be computed from the pressure record, and observations with one theo-

dolite used with these heights to determine horizontal distance from the starting point. When pilot balloons are used, the rate of ascent can be fairly well determined by means of one of several formulæ, based upon the weight of the balloon, its resistance to the air and its ascensional force. It any case the position of a free balloon can

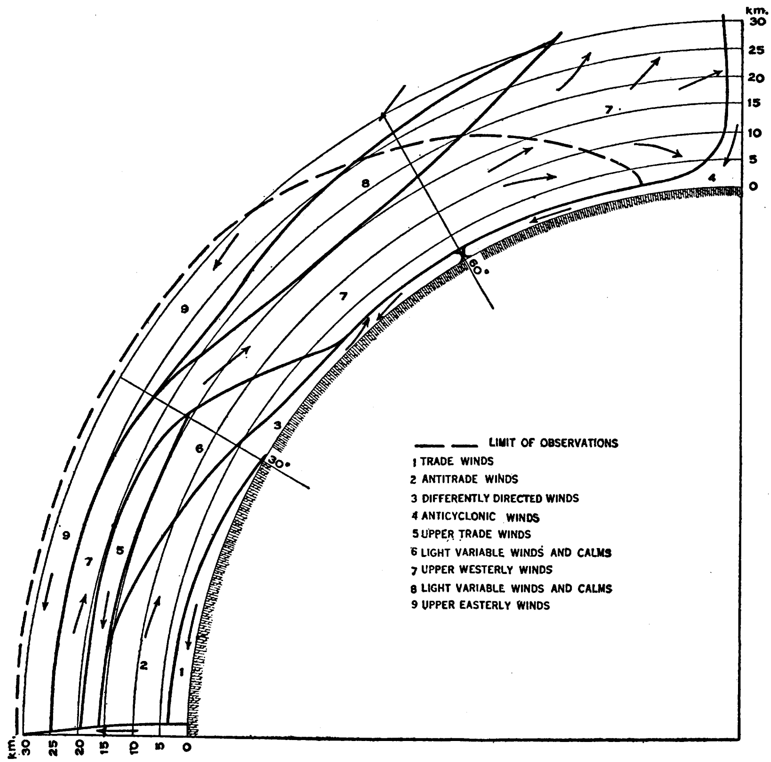

FIG. 3. Meridional section of the atmosphere.

be determined independently of the barometric pressure or of the ascensional rate of the balloon if a pair of theodolites, one at either end of a measured base line, is used. By means of any of these methods the observer is able to plot a horizontal projection of the balloon's path. From this plot may be read the wind speed and direction at any time during the ascension.

One of the first cares of the aëronaut is to put down suitable stations at which aircraft may be housed and repaired. It is im-

portant that these stations and their buildings be easily accessible to aircraft. A knowledge of the prevailing meteorological conditions is therefore of prime importance in the location of any station and in the orientation of its buildings. Among the climatic condi-

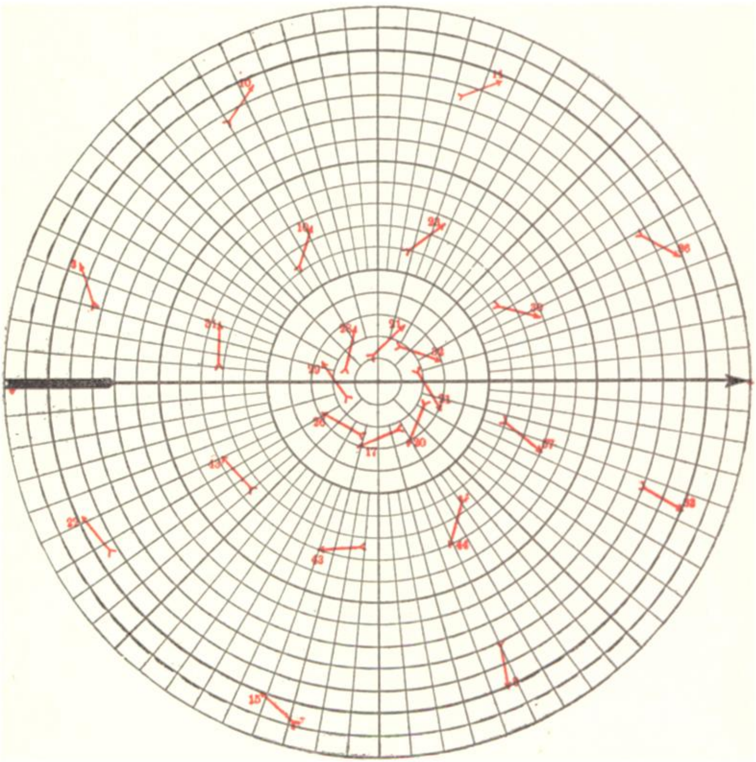

FIG. 4. Mean of Wind Observations in "Highs" at 526 Meters above Sea Level, 1907–1912.

tions that need consideration in this connection are cloudiness, rain, (including thunderstorm frequency), fog, humidity, temperature, pressure and wind. Of all these wind is the most important. It is an advantage to a station if the wind has a decidedly prevailing direction. Buildings housing aircraft can then be so oriented as to be easily accessible most of the time.

The Weather Bureau records can supply such information as that shown in Figs. 1 and 2 for many other stations than are here

included. In addition to surface conditions it is well if a knowledge of free air conditions to heights well above neighboring trees, buildings, hills or mountains can be known before deciding on the location of a station.

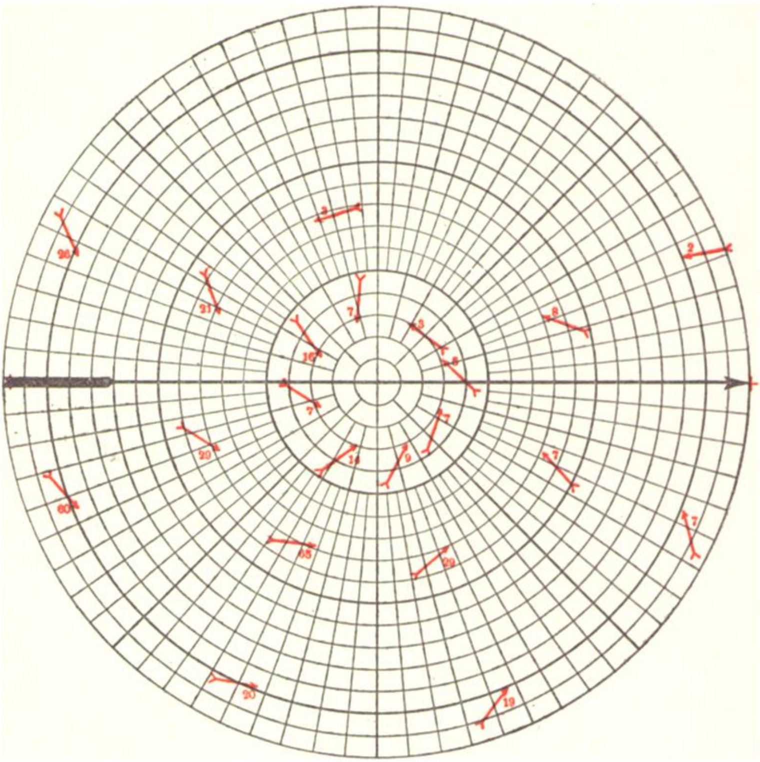

FIG. 5. Mean of Wind Observations in "Lows" at 526 Meters above Sea Level, 1907–1912.

The course to be pursued by a pilot flying between two stations should be governed by the structure of the atmosphere at the time and places in question. A knowledge of the relations that have been found to exist between surface and upper air conditions will be of value to the pilot, but cannot in general take the place of direct observations. By means of the observations, results of which could be available at the starting point of the course within half an hour after the observations were started, it would be decided whether

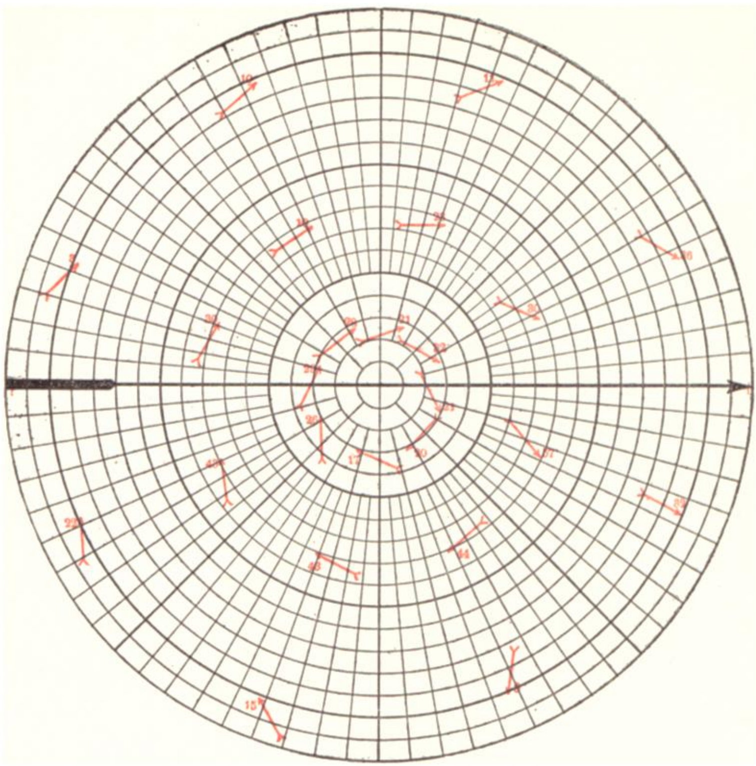

FIG. 6. Mean of Wind Observations in "Highs" at 1000 Meters above Sea Level, 1907–1912.

a direct course at the usual height or some deviation, lateral or vertical, from such a course should be made. Data sufficient for "laying" the course and determining beforehand the time required to travel it would be furnished by the observations. The pilot would to a great extent, if not altogether, be independent of having to see the earth's surface in order to know his direction and position at any time.

The different convective systems or circulatory systems of the atmosphere, together with the temperature distribution characterizing each, are of especial interest to aëronauts.

Fig. 3 shows a meridional section of the atmosphere, so far as it can be determined from observations now at hand. For the purpose

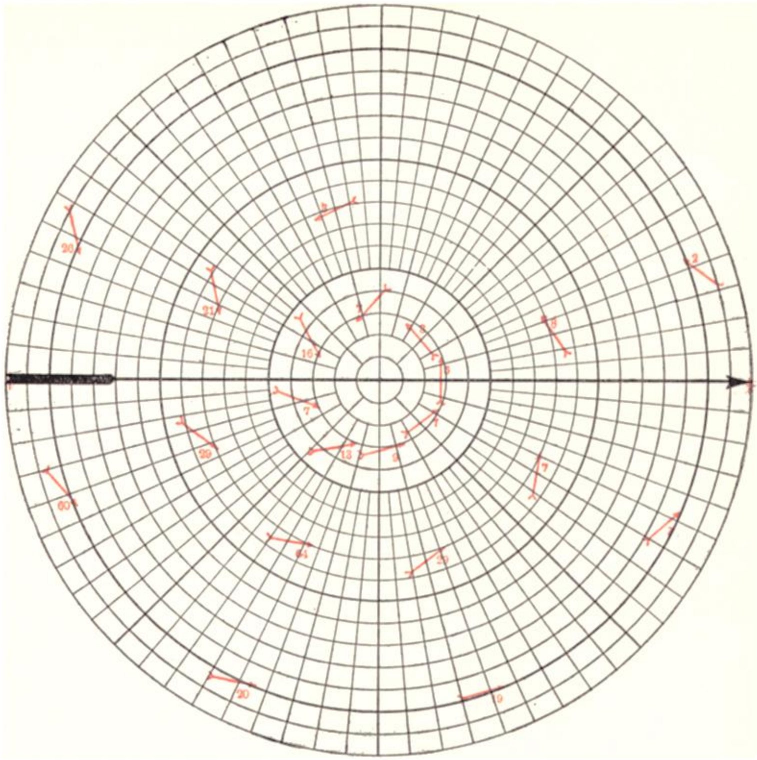

FIG. 7. Mean of Wind Observation in "Lows" at 1000 Meters above Sea Level, 1907–1912.

of this illustration the depth of the atmosphere shown is greatly exaggerated. The units of this general or planetary circulatory system in which the arrows point south are east winds having in the average a north component. Those units in which arrows point north are in general west winds having in the average a south component.

Especial attention is called to the fact that the air in west winds exerts a greater downward pressure than does the air in east winds. Aside from the fact that a gram mass moving from west to east exerts a greater downward pressure than does a gram mass moving from east to west, it is found that the air in west winds is in general dense for the level it occupies, while the air in east winds

is light for its level. That air is heavy or light for the level it occupies depends upon its humidity and its temperature and on the fact that descending air heats at the adiabatic rate while condensation of the moisture in ascending air offsets to a greater or less degree the adiabatic cooling that accompanies the ascent. It is also true that, compared with moist air, dry air absorbs but little radiated

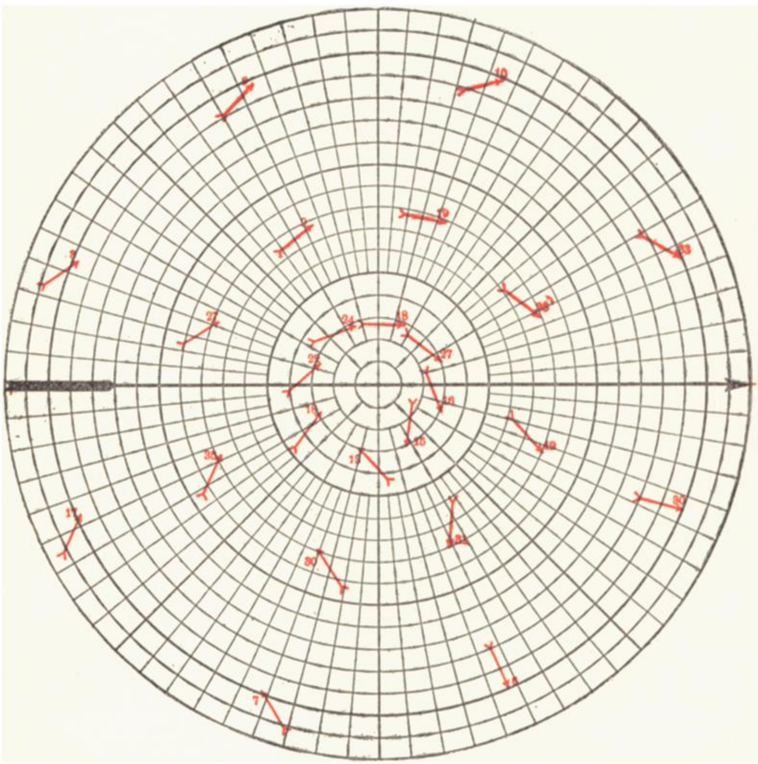

FIG. 8. Mean of Wind Observations in "Highs" at 2000 Meters above Sea Level, 1907–1912.

heat. This difference in adiabatic rates of cooling and heating effectively prevents the mixing of the airs in question. The west winds in general follow the irregularities of the bottoms, solid earth, water, or aërial, over which they flow and are in consequence gusty winds. East winds are not likely to be thrown into gusts by irregu-

larities of surfaces below them. They are in general less gusty than are west winds.

Closely related to this arrangement of light and heavy airs is the fact that the two regions of traveling storms, the tropical hurricanes and the high and low pressure areas of middle latitudes, are found where air relatively dense for the level it occupies is flowing over

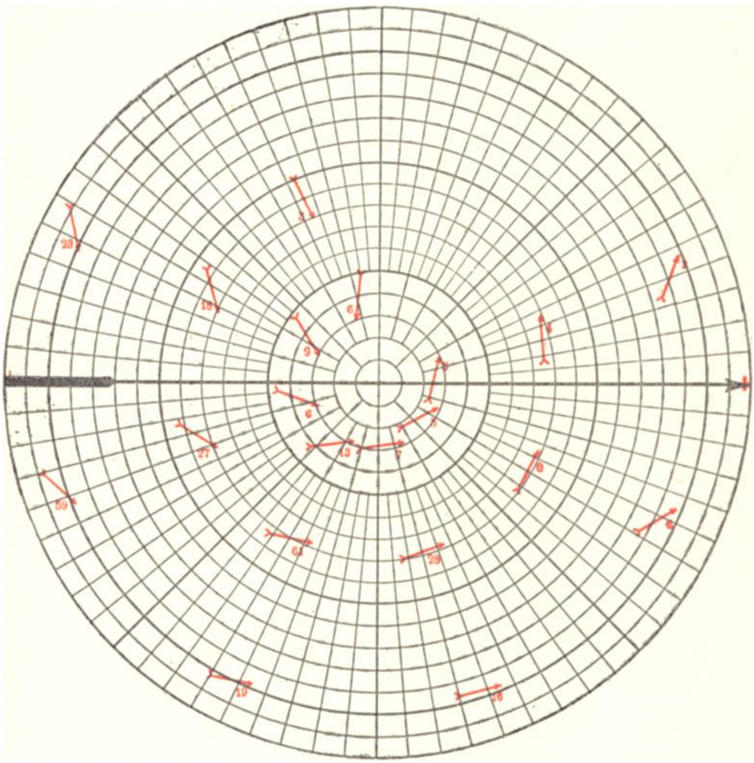

FIG. 9. Mean of Wind Observations in "Lows" at 2000 Meters above Sea Level, 1907–1912.

moister and, for its level, relatively light air. These storms are surface stratum phenomena, forming on the boundaries of warm, moist and cold, dry air masses and have approximately the speed and direction of the wind in the stratum immediately above them. The tropical hurricanes have the speed and direction of the antitrade

winds where the latter flow over the trades, while cyclones and anticyclones have the speed and direction of the upper westerlies. The data seem to show that cyclonic disturbances form on the left side of oppositely directed, passing currents of air in the surface stratum, while anticyclonic disturbances form on the right side. The airs in these two sorts of currents are differently tempered and of different moisture content, the extent of these differences having to do with the intensity of the disturbances. These irregularities in pressure distribution behave toward the upper westerly wind, or, in the case of tropical hurricanes, toward the antitrades, as variations in the level of the surface over which they flow. The disturbances are thus communicated directly to the upper winds which

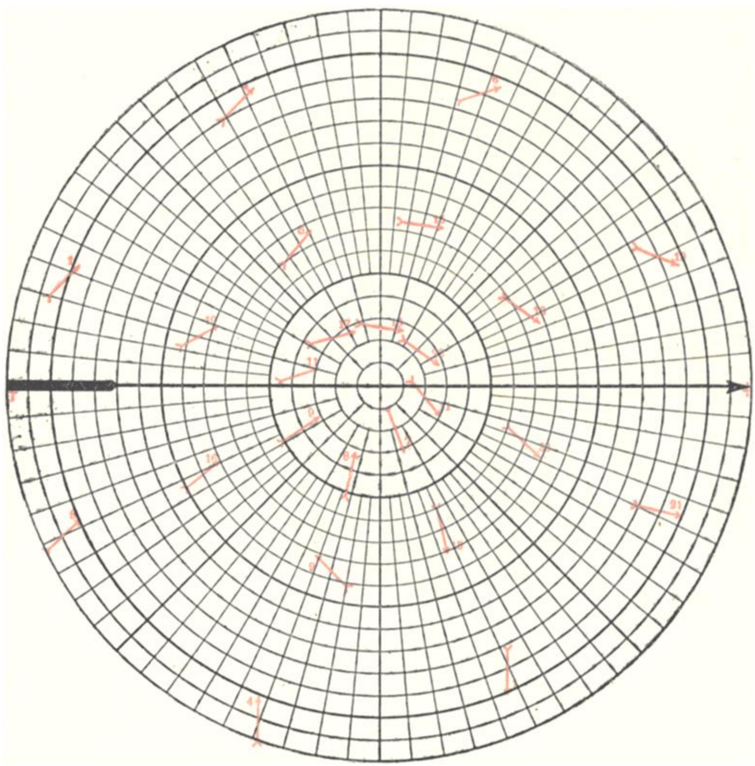

FIG. 10. Mean of Wind Observations in "Highs" at 3000 Meters above Sea Level, 1907–1912.

thus become gusty, just as do winds flowing over irregularities in the earth's surface. These gusts are accompanied by appropriate changes in pressure and temperature, and progress in the direction and with the speed of the wind in which they occur. They carry with them the self-sustaining disturbances of the lower or surface stratum which would otherwise be practically stationary phenomena.

Figs. 4 to 15 inclusive show the direction of the winds about centers of high and low pressure at the earth's surface and at levels above these centers. All winds, whatever their direction at the earth's surface, change direction with altitude in such a way as to become westerly by the time the four kilometer level has been reached. This tendency is shown by a comparison of surface winds

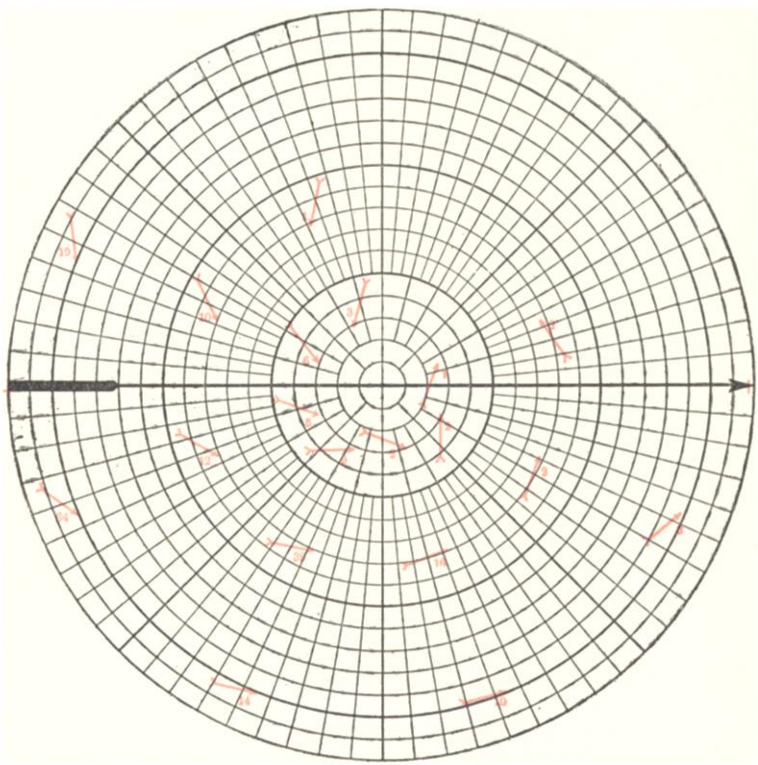

FIG. 11. Mean of Wind Observations in "Lows" at 3000 Meters above Sea Level, 1907–1912.

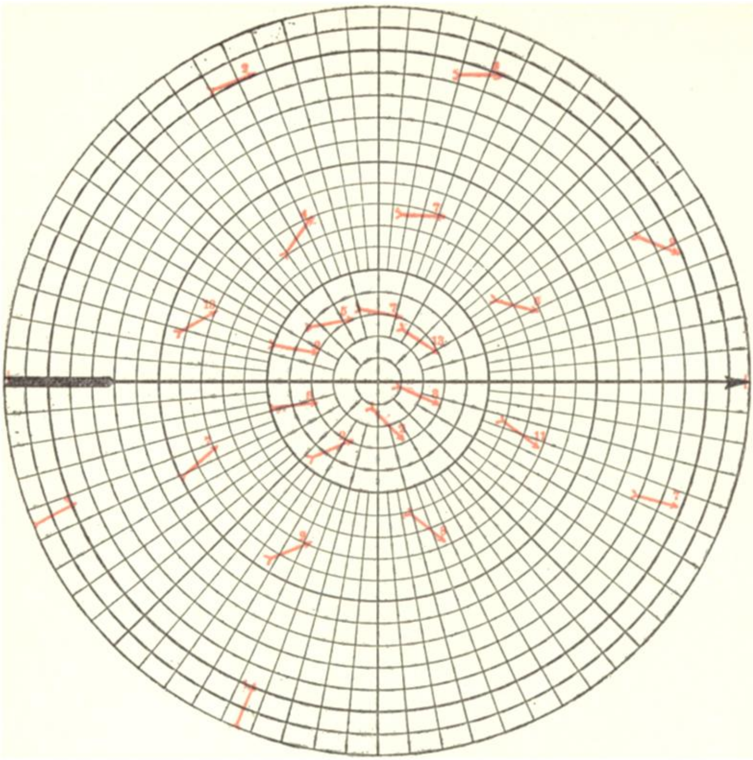

FIG. 12. Mean of Wind Observations in "Highs" at 4000 Meters above Sea Level, 1907–1912.

TABLE I.

TURNING OF WIND WITH HEIGHT.

Direction at Earth's Surface.	No. of Observations.	Clockwise, Per Cent.	Counter-clock-wise, Per Cent.	None, Per Cent.
N. to ENE	31	45	35	20
E. to ESE	50	76	12	12
SE. to SW	474	94	2	4
WSW	46	76	7	17
W	109	51	12	37
WNW	298	41	29	30
NW	337	29	40	31
NNW	34	35	38	27

with those at the one kilometer level. By the time the three kilometer level has been reached, it is probable that isobars are no longer

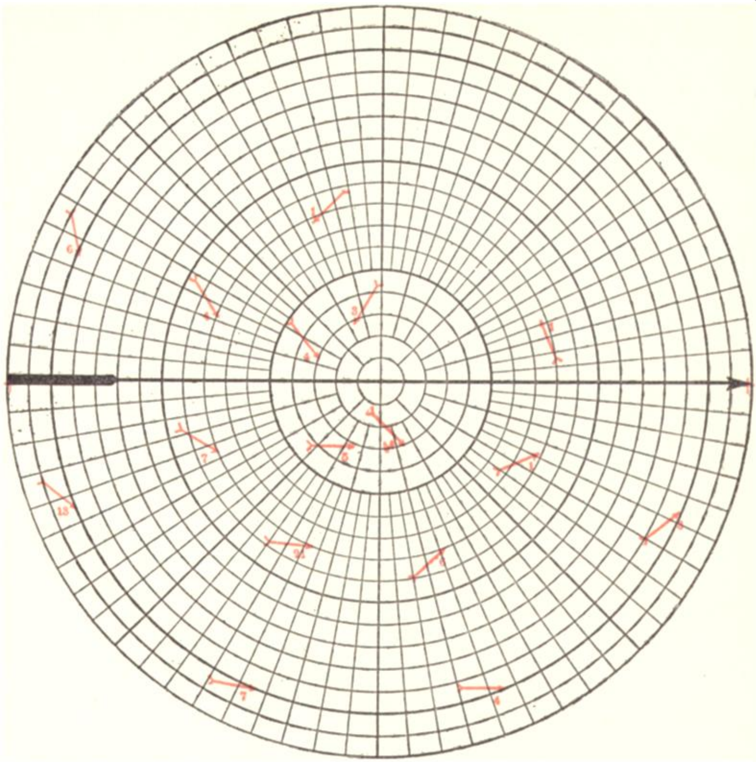

FIG. 13. Mean of Wind Observations in "Lows" at 4000 Meters above Sea Level, 1907–1912.

closed. The change in direction of the wind with height may be shown in a general way by Table I., based upon data obtained at the Mount Weather Observatory.

Tables II. and III. show frequency and speed, respectively, of winds at different levels above Mount Weather. Table II. indicates the decided increase in frequency of west and westerly winds with height. The increase in wind speed with height is rapid for the first 500 to 700 meters above the earth's surface, less rapid at higher levels.

In the study of any convective system the temperature distribution in the system is of prime consideration. The vertical distribution of temperature is of interest to the aëronaut, not only in connec-

tion with the filling and ascensional rates to be expected of balloons but also as the best available index of the condition of the atmosphere with respect to stability.

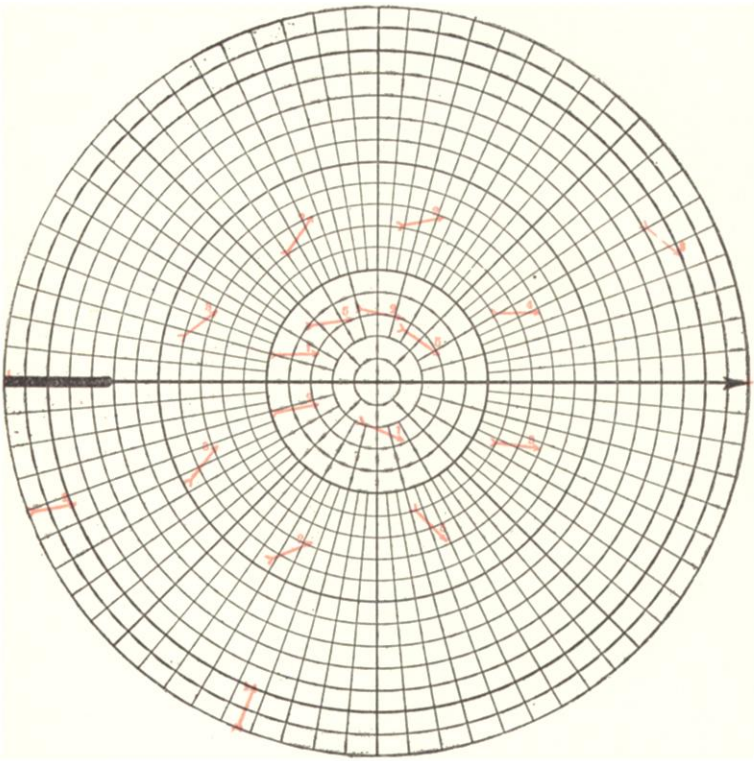

FIG. 14. Mean of Wind Observations in "Highs" at 5000 Meters above Sea Level, 1907–1912.

Fig. 16 shows the temperature distribution throughout the year up to the five-kilometer level. It is based on 5 years of observation at Mount Weather. The isotherms are farther apart vertically in the winter than in the summer months, indicating less stable atmospheric conditions in the summer months. The decrease in the amplitude of the annual variation of temperature with height is apparent; also, the difference in rates of rise and fall of temperature before and after the annual maximum.

Fig. 17 shows the vertical distribution of temperature to be expected in the different quadrants of the high-pressure area, based on five years of observation at Mount Weather, while Fig. 18 con-

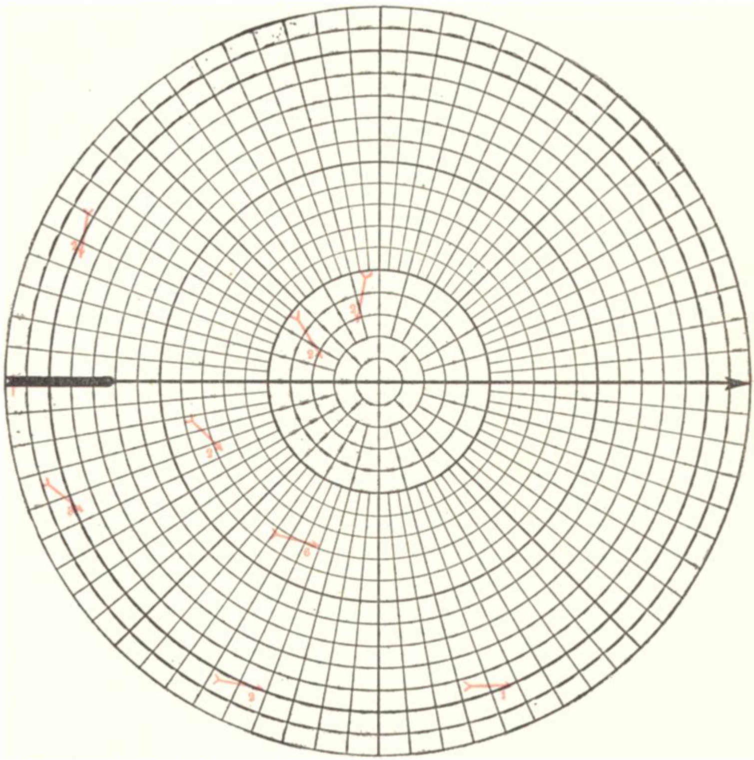

FIG. 15. Mean of Wind Observations in "Lows" at 5000 Meters above Sea Level, 1907–1912.

tains similar information for low-pressure areas. The temperature-altitude relation for a condition of neutral equilibrium in the atmosphere would be represented on one of these charts by a line drawn at an angle of 45° to the axes. Such a gradient is more nearly approached by average conditions in the high-pressure areas of the summer months than elsewhere, but the height to which it extends does not often exceed 1,500 meters in these latitudes.

Other convective systems than the planetary are in independent

TABLE II.

RELATIVE FREQUENCY (PER CENT.) OF WINDS FROM THE DIFFERENT DIRECTIONS OBSERVED AT EACH LEVEL.

Wind Direction.	Altitude of Each Level (Meters).											
	526.	750.	1,000.	1,250.	1,500.	2,000.	2,500.	3,000.	3,500.	4,000.	4,500.	5,000
N	0.2	2.5	2.2	1.7	2.0	2.8	2.2	1.9	1.8	...	...	...
NNE	...	...	1.1	1.2	1.8	1.6	2.2	1.9	1.2	1.9	1.7	...
NE	0.4	...	0.4	0.4	0.2	...	...	...	...	...	...	...
ENE	0.4	0.2	0.2	0.4	...	...	...	...	...	...	...	...
E	3.5	1.6	0.9	0.8	0.8	0.5	...	...	...	...	...	...
ESE	2.6	2.0	2.2	1.0	0.8	...	...	...	...	...	...	...
SE	14.1	3.2	2.4	2.1	0.8	0.2	0.3	...	...	...	...	...
SSE	9.6	10.6	6.2	3.7	2.0	0.9	...	...	...	...	...	...
S	7.5	12.4	12.4	9.0	6.4	2.5	0.8	0.7	...	...	...	...
SSW	0.7	6.5	7.6	11.5	10.4	8.8	7.8	5.6	3.6	1.0	...	...
SW	2.1	3.4	5.6	8.0	10.0	12.5	14.1	13.0	13.6	9.4	6.9	12.5
WSW	3.5	3.4	4.9	5.6	6.8	7.6	7.2	13.0	15.4	16.0	8.6	4.1
W	8.9	7.4	7.6	8.7	10.2	18.1	23.0	22.7	21.9	28.3	36.2	50.0
WNW	26.4	20.1	19.5	18.8	19.0	19.7	18.8	21.3	25.4	31.1	29.3	12.5
NW	17.0	19.4	19.3	19.5	19.2	17.8	18.3	14.5	13.6	8.5	12.1	8.3
NNW	3.3	7.2	7.6	7.5	9.4	6.9	5.3	5.6	3.6	3.8	5.2	12.5

operation. They are set up locally because of peculiarity of topography of the earth's surface or in its nature so far as ability to absorb and radiate heat is concerned. The variation in the intensity of insolation during the twenty-four-hour period also gives rise to a convective system which is of especial interest to the aëronaut. Figs. 19 and 20 show the temperature distribution up to the three-kilometer level accompanying the diurnal convective system, as it has been observed at Mount Weather on clear days. Fig. 19 is based on data for the summer half of the year and Fig. 20 for the winter half. The horizontal circulation that obtains in this convective system is not often in direct evidence. It usually manifests itself as a modification in the direction and speed of the wind prevailing at the time and need not now be further considered. The height to which turbulence in the air, caused by the heating of the earth's surface during the day, extends and the time of greatest activity in this stratum are shown to be, on the average, between 1.5 and 2 kilometers above sea level in the summer months, between 1 and 1.5 kilometers in the winter months. The height of the observing station on the Blue Ridge was 526 meters above sea level.

TABLE III.

Mean Velocity of Winds from Each of the 16 Points at Each Level. Year.

Wind Direction.	526 (Surface).		750.		1,000.		1,250.		1,500.		2,000.		2,500.		3,000.		3,500.		4,000.		4,500.		5,000.	
	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p.s.	Number of Observations.	Mean Velocity, m.p s.
N	1	2.8	14	9.2	12	11.9	9	11.3	10	9.6	12	10.4	8	10.5	5	14.5	3	13.2	...	...	...	...	...	...
NNE	...	...	...	...	6	12.8	6	10.7	9	9.4	7	10.1	8	10.3	5	13.9	2	14.4	2	17.2	1	24.5	...	...
NE	2	3.6	...	...	2	7.2	2	7.9	1	7.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
ENE	2	4.7	1	8.5	1	10.2	2	10.4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
E	20	5.6	9	8.7	5	10.4	4	8.1	4	8.0	2	15.0	...	...	...	...	...	...	...	...	...	...	...	...
ESE	15	6.5	11	7.4	12	9.3	5	9.8	4	10.1	...	...	...	...	...	...	...	...	...	...	...	...	...	...
SE	81	8.0	18	9.3	13	9.1	11	9.3	4	9.9	1	9.0	1	18.3	...	...	...	...	...	...	...	...	...	...
SSE	55	7.7	59	10.9	34	11.7	19	9.4	10	7.2	4	10.4	...	...	...	...	...	...	...	...	...	...	...	...
S	43	6.5	69	12.0	68	10.8	47	13.4	32	14.0	11	12.5	3	12.5	2	12.8	...	...	...	...	...	...	...	...
SSW	4	5.7	36	11.5	42	14.0	60	14.4	52	14.9	38	16.2	28	17.4	15	19.1	6	22.8	1	24.6	...	...	...	...
SW	12	5.9	19	10.9	31	13.5	42	14.8	50	15.9	54	15.6	51	16.8	35	18.3	23	20.3	10	22.2	4	19.4	3	22.7
WSW	20	6.6	19	10.0	27	15.3	29	15.8	34	15.3	33	16.0	26	18.1	36	21.2	26	21.7	17	22.6	5	25.5	1	18.0
W	51	8.0	41	12.0	42	14.6	45	17.3	51	18.9	78	19.9	83	21.4	61	21.7	37	22.2	30	22.4	21	24.2	12	26.2
WNW	152	10.7	112	13.1	107	13.8	98	16.3	95	16.9	85	17.1	68	17.6	58	19.4	43	20.7	33	24.3	17	23.7	3	27.8
NW	98	10.0	108	13.3	106	12.4	102	15.4	96	16.4	77	18.1	66	19.3	39	20.1	23	21.1	9	19.7	7	24.5	2	23.7
NNW	19	6.8	40	10.9	42	12.9	39	13.5	47	12.9	30	13.8	19	14.5	15	17.5	6	22.2	4	21.6	3	22.3	3	25.7

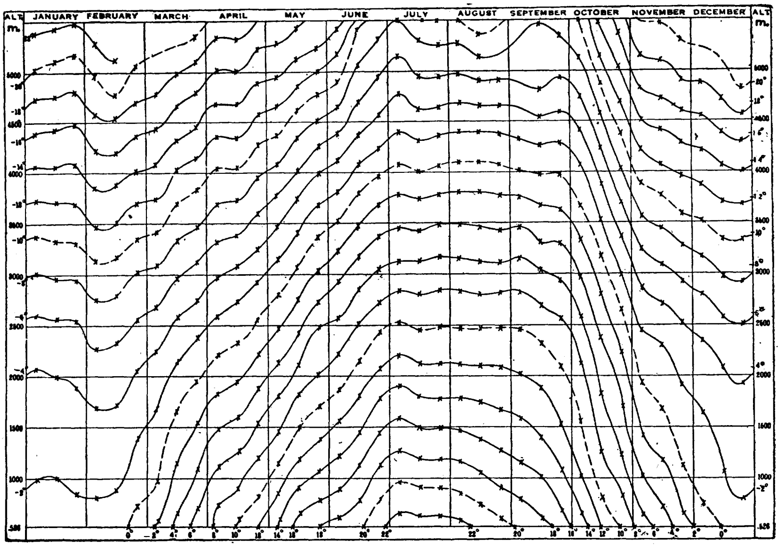

FIG. 16. Mean free air temperatures above Mount Weather, Va.

the station being 300 meters higher than the floors of the valleys on either side of the Ridge. Aërial navigation in this turbulent region is considerably more difficult than it would be outside the limits of the region.

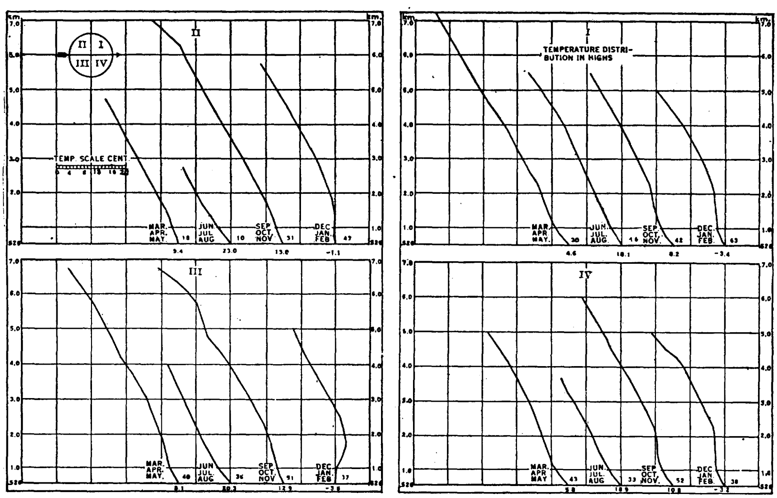

FIG. 17. Temperature distribution in highs observed at Mount Weather.

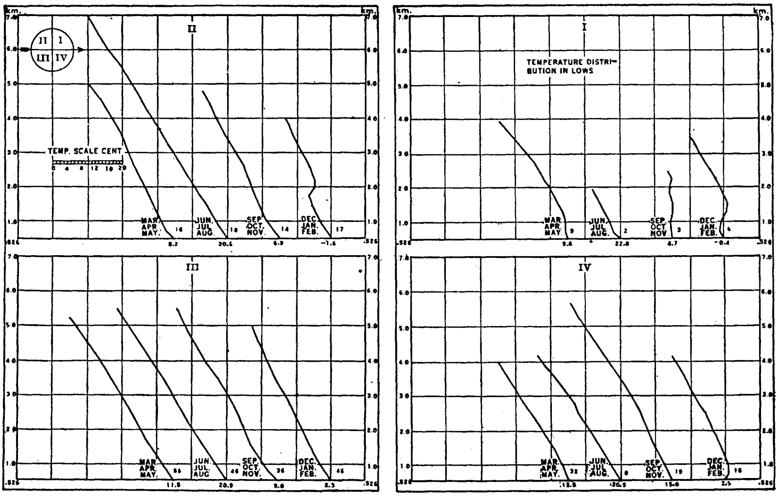

FIG. 18. Temperature distribution in lows observed at Mount Weather.

The gustiness of the wind is also a source of some difficulty to the aëronaut. This is especially true of surface winds because here the gusts follow each other at shorter and less regular intervals than do those occurring in winds at the higher levels. Each gust con-

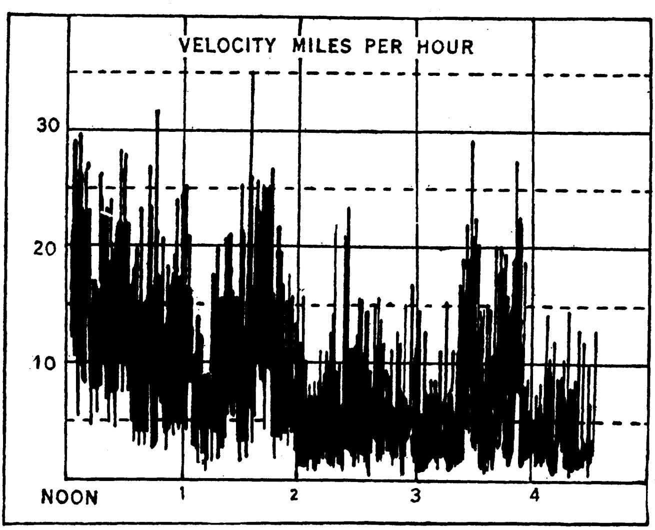

FIG. 22. Record of wind speed and force by pressure tube anemometer.

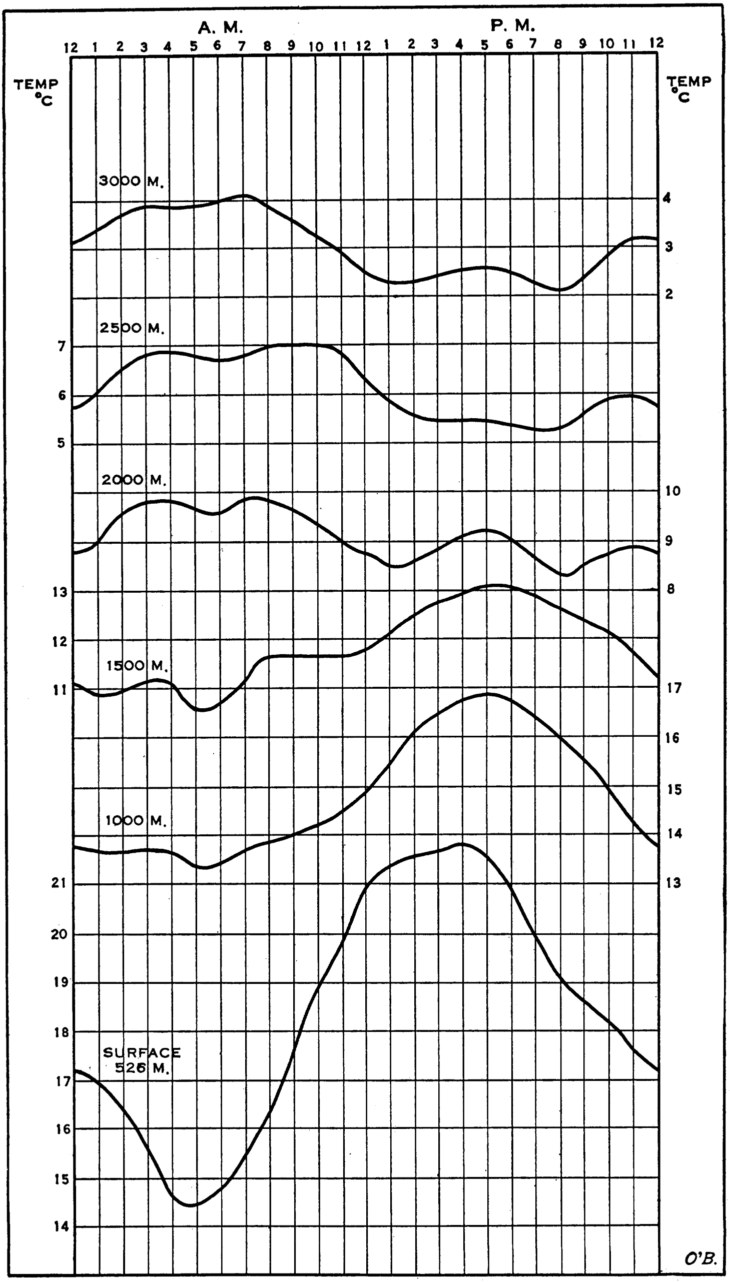

FIG. 19. Diurnal distribution of temperature for the summer half of the year at different levels above Mount Weather.

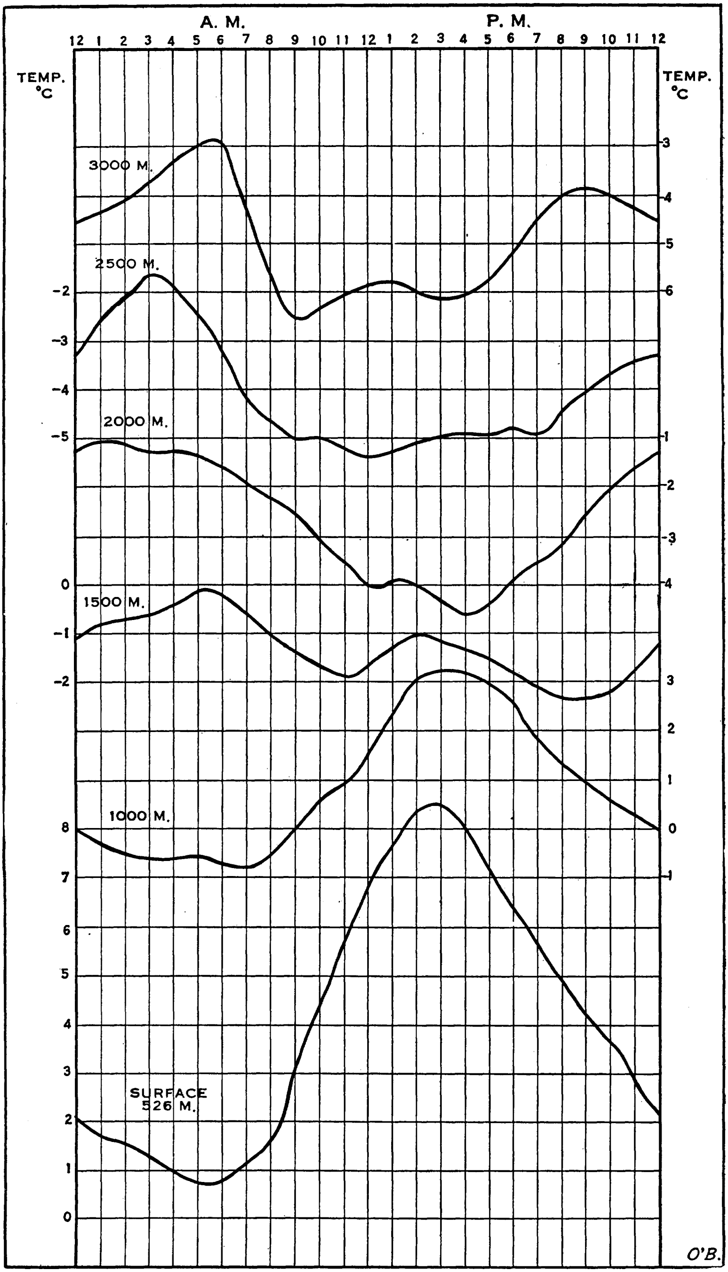

FIG. 20. Diurnal distribution of temperature for the winter half of the year at different levels above Mount Weather.

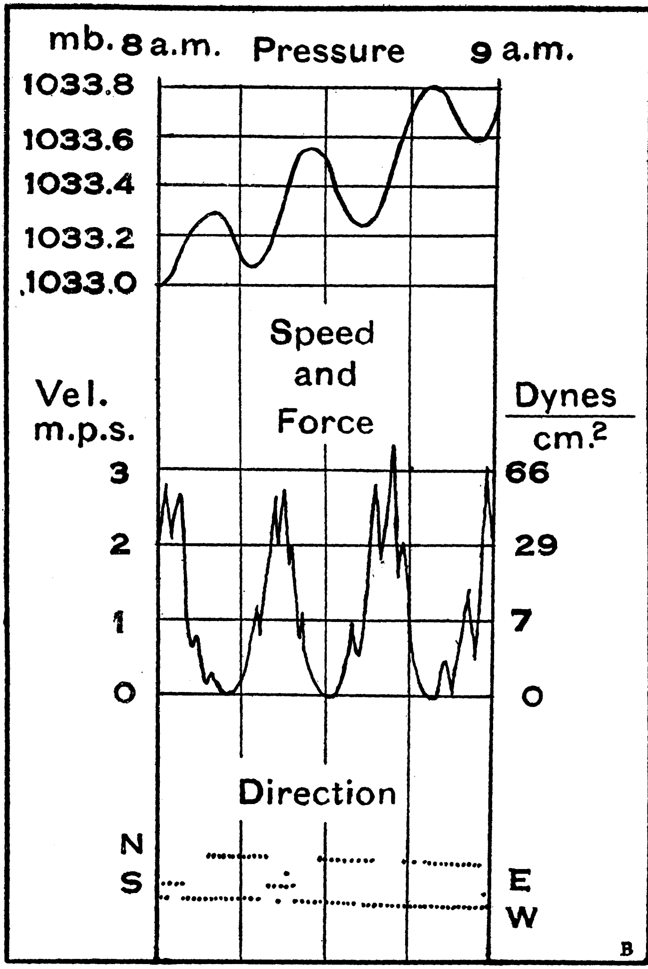

FIG. 21. Relation between speed, force, pressure and direction in wind gusts.

sidered separately is a complete convective unit in which occur appropriate changes in air pressure, temperature and in speed and direction of movement. Fig. 21 illustrates a series of changes in wind speed with accompanying changes in wind direction and air pressure. Fig. 22 (see page 207) is a part of a record made by a pressure tube anemometer showing frequency and amplitude of gusts as they occur in the average westerly wind. The acceleration in the hori-

zontal component of the wind speed shown is about 7.5 centimeters per second. It would require a horizontal acceleration of 17 to 20 times this amount to sustain a bird or a well-constructed glider in soaring flight, but together with the changes in direction in the horizonal plane recorded by our instruments, vertical changes in direction occur in these gusts which are really only a series of expansions and contractions in the moving air.

When the air expands and contracts with sufficient rapidity, the vibrations become audible. The use of these vibrations and possibly of aërial vibrations of still higher frequency in detecting the presence of aircraft or as a means of communication between aircraft or to receiving stations is outside the scope of this paper.

The subject of atmospheric electricity and possibly closely connected with it the loading of aircraft with liquid or solid H_2O are also matters of interest to the aëronaut. So far not much has been done toward the solution of the problems arising from these atmospheric conditions. It is likely that the solid formations, both crystalline and amorphous, occur more readily, if not altogether, on electrically charged surfaces.

U. S. Weather Bureau,
Washington, D. C.